# National Bureau of Standards

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U.S. DEPARTMENT OF COMMERCE

# Contents

# Foreword

FOR over 80 years the National Bureau of Standards has provided the basis for uniform and accurate measurements throughout the U.S. economy. When the Bureau was established most precision measuring instruments were foreign-made. Even those produced in the United States had to be calibrated abroad. Many measurement procedures were inadequate—as in the newly emerging area of electricity measurements. Manufacturers lacked standards and methods for assuring quality control in the production of materials and products. They needed a better understanding of the materials they were working with.

Since then NBS research has laid the groundwork for undreamed of advances in electricity, aviation, automotive engineering, and materials. It has provided essential improvements in electrical standards and developed better standards of length and new standards of light, temperature, and time. In fact, frequency measurements completed recently by NBS scientists make it possible for the first time to tie all measurements of time and length to a single very precise standard. And, the Bureau has pioneered work in aeronautics, radio, and cryogenics.

Today, as always, our goal is to maintain and improve the Nation's measurement capabilities. By doing so, we contribute directly to the competitiveness of U.S. industry, we help other Federal agencies and State and local governments to meet their goals, and we assist the scientific and engineering communities as they search for solutions to their measurement problems.

Of course, our programs change in response to new demands. Years ago we checked the accuracy of railroad watches against a standard pendulum clock; today, our cesium-beam clock can be referenced nationwide via radio and satellite broadcasts. But our basic mission—that of serving the Nation's economy by providing technical support—is unchanged.

As a nonregulatory agency of the U.S. Department of Commerce, NBS provides the measurement foundation needed by an industrial economy. By this I mean we work on the standards, measurement techniques, reference data, test methods, and calibration services that help to ensure national and international measurement capability and compatibility. We have, for example, developed linewidth measurement methods and artifacts that the semiconductor industry uses to calibrate its process instrumentation and research equipment. In another case, we have designed a system called resonance neutron radiography, a powerful new tool for inspecting objects without damaging them.

The value of our work grows in direct proportion to its responsiveness and usefulness to others. A prime example of our close collaboration with our clients is the Research Associate Program. Since the 1920's scientists and engineers working for various private organizations have come to the Bureau to undertake projects of mutual interest. Through the program, NBS is now hosting over 100 scientists and engineers who are working with NBS researchers on a wide range of projects, including materials research, analytical chemistry, standard reference data, and time and frequency measurements.

The program gives research associates the opportunity to develop, learn, and take new skills back to their companies and organizations. It also allows them to benefit from the use of NBS facilities and from collaboration and consultations with the NBS professional staff. At the same time, NBS gains the services of highly trained professionals and learns firsthand the views and needs of the industrial community.

With the information we get from these interactions—as well as many others—we determine the measurement capabilities required to facilitate the prompt introduction of new technologies that will strengthen our economy. As you read through this report of our work over the past 2 years, you will see we are working today to lay the measurement foundation for the technologies our clients will be using tomorrow.

**Ernest Ambler**
Director

# National Engineering Laboratory

FROM basic studies of the subtle behavior of microelectronic circuits to its work in engineering standards, the staff of the National Engineering Laboratory apply the Bureau's resources and basic skills in scientific measurement to a broad spectrum of national concerns.

NEL scientists and engineers conduct research in engineering and the applied sciences, studying problems in electronics, automation and manufacturing, chemical engineering, the behavior (and prevention) of fires, and the design and construction of buildings. NEL research and services in applied mathematical and computer sciences support technical programs throughout the Bureau.

Selected examples of research in these areas over the past 2 years follow.

## *Anticipating Calibration Needs*

One activity cuts across all NEL programs: measurement, or calibration, services. NEL provides measurement services for mass, force, fluid flow, density, humidity, microwave power, antennas, accelerometers, laser power, and electrical metering. For example, the watt hour meter calibration is the basis for ensuring accurate electric utility bills for every homeowner or apartment dweller in the United States. NEL, also, maintains the world's standard against which it calibrates transfer gauges for the threads of pipes used in drilling oil wells—a service that is of growing importance with the trend to deeper oil wells.

Greater use of rapidly changing technologies such as digital signal processing, optical fiber transmission, and higher data transmission rates has sparked demand for new or improved calibration services from the Bureau. For instance, NEL has initiated a new calibration service for analog-to-digital (A/D) and digital-to-analog (D/A) data converters, vital elements of modern measurement equipment which link analog phenomena to the world of digital computing and data processing.

Based on a special reference 20-bit D/A converter developed by NEL engineers, the new calibration service supports a class of devices with an estimated annual market of $600 million. The service will help manufacturers and users of A/D and D/A converters meet a variety of measurement needs, including testing individual converters destined for highly demanding applications, satisfying traceability requirements imposed by military or government contracts, verifying their own test procedures through the use of transfer standards, checking the performance of converters used in automatic test equipment, and testing experimental converter designs during development.

To help assure the speed and accuracy that will be required in future services, NEL researchers have developed and demonstrated on a research basis an A/D signal converter that is the fastest yet produced. This device, based on superconducting Josephson junction technology, can deliver 6-bit resolution for 4 billion samples per second. Data conversion rates of this order will be required for metrology in emerging digital transmission and radar systems and for a coming generation of measurement systems for very fast transient events. NEL researchers are working to improve the capability of the device, a key element of the metrological capability needed to support the ultra-high-speed technology of gigabit electronics.

Josephson junctions are also the basis of a number of extremely sensitive measurement devices and standards used at NBS. NEL researchers recently made a valuable addition to our knowledge of the behavior of these devices. Using sophisticated methods of computer modeling and numerical analysis, they are studying "chaos" in Josephson junctions.

"Chaos" is the name researchers have given to what—theoretically—can happen in a wide variety of physical systems. Under certain narrow conditions, systems which usually follow comparatively simple, rigid mathematical patterns behave very erratically. NEL researchers showed that chaotic behavior can take place in Josephson junctions, under the right conditions, and seriously affect the performance of the instrument involved. Such behavior has been confirmed through indirect experiments. Mathematical models like the one produced in NEL demonstrate that this rather esoteric phenomenon can take on a practical importance for instrument designers.

## *Measuring Electromagnetic Radiation*

The effects of electromagnetic radiation and problems with electromagnetic interference are of concern to all levels of government, industry, and the public. Existing measurement techniques and instrumentation are inadequate for determining the characteristics of the electromagnetic envir-

onment or the susceptibility of electronic components to that environment.

NEL researchers are improving techniques for measuring electromagnetic radiation and for measuring the response of electronically controlled devices to such radiation. For example, NEL's electronic engineers have developed two portable field monitors to measure electromagnetic radiation: one measures the electric field and the other the magnetic field component.

The isotropic electric-field monitor (EFM-5) covers the frequency range 200 kHz to 1000 MHz, which includes the AM, FM, and TV broadcast bands as well as special industrial applications. It responds to a wide range of signal strengths with an accuracy of ±2 dB. Now produced commercially, the EFM-5 is completely self-contained, portable, and intended for use by one person in a variety of environments.

The portable, isotropic magnetic-field monitor (MFM-10) gives accurate magnetic field measurements over the frequency range 300 kHz to 100 MHz. Operating in this range are high-power industrial sources of radio-frequency energy such as sealers, gluers, dryers, and induction heaters; the range also includes all the commercial AM and FM radio bands, TV channels 2 through 6, most amateur radio bands, and low-frequency industrial bands. Developed in cooperation with the National Institute for Occupational Safety and Health, MFM-10 was designed for characterizing workplace environments that contain high magnetic-field components of electromagnetic fields.

## *Testing Integrated Circuits*

NEL's work on semiconductors provides the technical basis for voluntary standards for the buying and selling of semiconductor production equipment, materials, and devices. This effort responds to demands for new measurement capabilities, demands generated by the markedly smaller (micrometer and sub-micrometer) dimensions and the vastly increased complexity of very large scale integrated (VLSI) circuits. New testing concepts as well as tighter control of dimensions, material purity, and other parameters are required.

Since the 1970's, NEL research has provided the semiconductor industry with a number of special measurement tools—microelectronic test structures. Similar in design and construction to circuits used in integrated circuit "chips," test structures are used by manufacturers to evaluate the performance of their manufacturing processes and estimate the yield of a production run of integrated circuit chips. NEL researchers have designed a variety of structures to test key process parameters such as line width, sheet resistivity, and random faults in metal interconnects.

One of their most recent developments is a test structure for contact resistance, the electrical resistance that occurs at the points where two different conducting layers of an integrated circuit are connected through "windows" in an insulating layer. Until recently, contact resistance was considered a fairly minor factor in the performance of integrated circuits. With the trend toward VLSI, however, the size of features in an integrated circuit has become progressively smaller, while the number of individual features in a single circuit has increased dramatically. Smaller contact windows have meant larger values for contact resistance, and so this once rather unimportant factor is becoming more and more significant to the successful operation of the circuit. The new test structure for contact resistance not only manages the difficult task of making direct measurements of contact resistance, but also minimizes a number of "parasitic" resistances (those generally associated with the contact resistance) which have contributed to the uncertainty of earlier measurements of this factor.

Another NEL researcher has developed techniques to make extremely sensitive spreading resistance profile measurements of semiconductor devices. Both chemical stains and spreading resistance measurements on lapped bevels are used to measure the location and depth of doped junction regions in silicon chips, but modern implant technologies are producing such shallow layer depths and junction thicknesses that they are nearly undetectable at present measurement levels. The improved techniques make use of very shallow angle bevels (about a thousandth of a radian) to expose the various layers of the device. Careful preparation of both the specimen and the resistance probes permits measurement of resistance profiles of dopant layers as thin as 50 nanometers with a vertical resolution of 1 to 2.5 nanometers in some cases. Preliminary results suggest close to an order of magnitude improvement over previously published measurements.

## *Preparing for the Manufacturing Future*

The discrete parts manufacturing industries, which make parts for aircraft, automobiles, and machine tools, produce goods that account for 75 percent of all U.S. trade in manufactured goods. Although this sector of the U.S. economy includes 35 percent of all U.S. firms, 87 percent of them have fewer than 50 employees. These industries can reap significant benefits from automation, and it now appears they must automate to compete successfully in both foreign and domestic markets.

NEL provides the basis for measurement assurance including traceability to national standards and assists in the development of voluntary standards necessary for industry to automate successfully. NEL is now focusing its research efforts on the completely automated small-batch manufacturing system, which is made up of metal-cutting machines, computers, terminals, robots, conveyors, and measuring or inspection systems. Such a system produces a variety of shapes and sizes of parts and may proceed to assemble them into larger systems.

Historically, the Bureau has provided calibration services for measuring devices, such as micrometers, used in machine shops. As machined parts have become more complex, however, so have the measurement techniques, and it now takes nearly as much time to make the measurement as it does to machine the original parts. Further, the part is measured after it is made, thus the measurement serves to make a decision to accept or reject but does not directly affect the manufacturing process.

In the future, with the advent and availability of economical computers, it is likely that the process can be designed to make only acceptable parts. In principle, through "deterministic metrology," it should be possible to account for all the contributions to machine error, correct them in the software of the machine controller, and have a machine that cannot make a bad part—except in the case of mechanical failure in the system. NEL is working on the means and methods for providing traceability to national standards that will be consistent with this new way of looking at quality control.

These concepts are being applied by NEL to a fully computerized vertical milling machine, and they will be tested further in the automated manufacturing research facility (AMRF) being installed in the Bureau's machine shop. This is to be a small, modular flexible manufacturing system that will serve as a test bed to see if NEL's measurement concepts will provide the assurance required by industry.

NEL researchers work closely with their counterparts in private industry on this project, and industry has provided much valuable support. Already, in the early stages of the AMRF project, about a dozen private firms have assisted NEL with the loan of equipment and people. No fewer than eight industry-sponsored research associates are now working with NEL on the AMRF, and approximately $400,000 worth of equipment has been lent to the project.

The AMRF is also designed to be the test bed for the standards needed for interfaces in modular automated systems. NEL is primarily concerned with standards for the many interfaces between components of computer-aided manufacturing (CAM) systems and interfaces between the system and the design, planning, and control of the manufacturing operation. Wherever there is a pair of computer-aided components interacting, there is an interface. If the components are made by different manufacturers, they cannot be coupled directly except by custom-made software interfaces.

A series of non-proprietary interfaces, which permits two components to interact through it without revealing proprietary software, may be developed as a research base for consensus standards. In such cases, NEL works on the technical details, validates the procedures in the laboratory, and submits its results to the appropriate standards committees. For example, the American National Standards Institute recently adopted as a standard the Initial Graphics Exchange Specification (IGES), which was developed by an industry-government coalition managed by NBS. IGES permits data to be transferred from one computer-aided design (CAD) system to another CAD system of different manufacture and provides a first step toward allowing data transfer from CAD systems to CAM systems, robots, and other manufacturing components. NEL is now working on a more advanced version of IGES that will allow improved surface geometry and improve the handling of non-geometric data such as text and dimensional information.

## *Measuring Process Flow*

NEL provides the chemical process and associated industries with fundamental measurement science and critical data which enable them to calibrate their measurements—many of which must be made in harsh environments—to national standards and to obtain data essential for process design and control.

NEL researchers are working on new techniques to measure the flow of solid/fluid mixtures and to determine the flow stream composition, temperature, viscosity, and density. In addition, they are developing calibration services for fluid measurements needed for industrial process control and for equity in trading liquids and gases. For example, under the sponsorship of the American Petroleum Institute, NEL has begun a project to generate a new database for orifice meter performance. Orifice meters are widely used in gas pipelines to measure flow rates. The testing program will document pertinent background parameters and determine performance coefficients for a wide range of flow conditions in NEL's fluid meter calibration facilities. The resulting database will enable improved fluid measurement and custody transfer through millions of these meters around the world.

Thermophysical properties data are also needed for reactants and products in process streams. Predictive models are required to extend the measured data from a small set of measured substances to predictions of these data for many other substances over wider ranges of conditions.

NEL engineers have designed a model for the prediction of the density, viscosity, and thermal conductivity of broad classes of industrial fluid mixtures including such chemicals as ethylene, alcohols, and vinyl chloride; natural and synthetic gases; and coal, oil shale, and tar sand liquids. The computer model predicts transport properties of pure hydrocarbons and their mixtures through the carbon-20 molecular weight range across the entire range of pressure-volume-temperature (PVT) states. Known as TRAPP, the model is being distributed by the Gas Processors Association and the NBS Office of Standard Reference Data.

Chemical and process engineers require transport properties to design heat exchangers, compressors, pumps, and pipelines. Owing to the complexity of transport phenomena, most engineering calculations of transport properties are based on empirical correlations which are generally limited to narrow ranges of pressure and temperature and, very frequently, to pure fluids. To evaluate and validate predictive techniques, NEL researchers have constructed an apparatus that will measure the PVT relations in hydrocarbon, chemical, and petrochemical fluids. The experimental capability of the apparatus ranges from room temperature to 900 kelvin at pressures up to 35 MPa. This apparatus, which was tested by making PVT measurements on propane, will be used to provide property data for industrial chemicals of key interest to the industry, including toxic chemicals. For example, a measurement program using hydrogen sulfide is underway.

NEL researchers have also developed a new high-temperature optical fiber thermometer made from a single crystal sapphire which should aid in the measurement and control of high temperatures in chemical processes, gas turbines, and internal combustion engines. The optical fiber thermometer could also be used in power generation equipment, nuclear energy systems, weapons, and space applications.

In contrast to the present thermocouple standards that are based on calibration and interpolation between fixed points, the optical fiber thermometer is based on fundamental radiation laws and may be used to measure thermodynamic temperatures directly. Because of its accuracy and stability, the new thermometer could eventually replace the ANSI Type S thermocouple, which was originally developed in 1886 and is currently used to realize the International Practical Temperature Scale from 630.74 °C to 1064.43 °C. Moreover, the NBS optical fiber thermometer can extend this temperature range to approximately 2000 °C and has the potential to be 10 times more accurate than the existing standard. In gas streams, the device responds eight times faster than conventional measurement techniques. It also has lower heat transfer losses and, therefore, can measure temperatures at lower gas stream velocities. Measurements made with this thermometer are free from interference caused by strong nuclear and electromagnetic radiation fields.

## *Predicting Fire Growth*

Other NEL researchers are concerned about how things burn—and how to keep them from burning. NEL's fire research has three elements: study of fundamental phenomena, development of techniques to predict fire behavior, and development of proposals for more effective standards, codes, and practices to facilitate transfer and use of the new information. Techniques to predict fire behavior and hazards are essential for materials

manufacturers, designers, and code officials who must know the effects of changes in materials, configuration, ventilation, and connection to other parts of the building on fire growth and spread.

One technique used by NEL researchers is mathematical modeling. With mathematical models, researchers take what is known about fires and predict what would happen if a particular fire were to break out in different-sized rooms or under different conditions. Giving researchers a cost effective way to assemble a fire's separate components and processes for study, models help researchers see how these parts fit together and thereby further the understanding of fire as a physical and chemical phenomenon. The main goal of this research is to use models to predict how fires grow and the temperature and behavior of the gases and smoke they produce. Eventually it should be possible to use models to help design buildings and materials to meet higher standards of fire safety.

Researchers are also working on techniques for measuring the fire properties of materials. One technique determines the rate of heat release of materials in a room by measuring the oxygen consumed in the burning process. Researchers have used the oxygen consumption technique to measure the rate at which heat is released from selected upholstered furniture when it burns. They have also measured the overall rate of heat release in full-size rooms in which there is successive involvement of combustible contents and building materials. Successful prediction of the course of the fire indicates the size of the fire at a given time, the rate of fire growth, the time available for escape or suppression, and the types of suppressive action that will be effective.

Another factor affecting fire growth is soot formation. In large fires, the thermal radiation from soot aids flame spread and heat transfer. Inhalation of soot poses serious health hazards due to adsorption of toxic gases, and heavy smoke in a fire obscures vision and hinders escape. NEL scientists are conducting a long-term study of the fundamental chemistry and physics of soot formation. An understanding of soot formation processes in flames should greatly aid in the development of methods for reducing the amount of soot produced and in controlling its properties. At present there is little understanding of the soot formation process at the molecular level, that is, how small molecules grow rapidly to become soot particles.

NEL and NML studies have produced new data for proposed models of soot formation through investigations of the ion-molecule chemistry of hydrocarbon ions, thought to be key precursors, and fluorescence from polycyclic aromatic molecules, which are likely to be important building blocks in soot formation. In addition, using a new laser-based method that relies on the optogalvanic effect, NEL researchers have estimated the mass and diameter of very small soot particles in flames. Experiments using multiphoton ionization on nitric oxide and phosphorus oxide have shown that this technique is extremely sensitive for flame diagnostics. New studies have also increased our understanding of the radiant ignition of solid combustibles, including the importance of vapor phase absorption of radiation and the role of oxygen in surface ignition processes.

The vast majority of fire deaths are due to the inhalation of smoke or hot gases. Although carbon monoxide, a combustion product of most burning materials, has been widely considered as the primary cause of these deaths, laboratory tests and analyses of some fire victims have suggested that other toxicants or factors may contribute to some deaths. Product manufacturers, building officials, and others who want to know more about the toxicity of the combustion products of various materials have been handicapped by the lack of an agreed upon laboratory test.

NEL researchers recently developed and published a test method that product manufacturers and materials researchers can use to assess the acute inhalation toxicity of materials when they burn. The test, primarily intended for research and preliminary screening purposes, was developed in cooperation with representatives from industry, academia, and other government agencies. It involves heating a sample of material in a special furnace and exposing test animals (rats) to the combustion products. The materials are tested under both flaming and non-flaming conditions in an attempt to reflect two major modes of material decomposition. The NBS test will aid in assessing acute toxicity, but additional factors, such as the quantity of material present, ventilation conditions, and building occupancy, must be considered in evaluating the potential toxic hazard posed by a material in a given situation and in making decisions about the suitability of materials for a particular use.

## *Improving Structural Safety*

NEL carries out laboratory studies of the structural performance of buildings to provide the technical basis for building design criteria and measurement methods. This work is relied upon by various private sector

organizations in the development and issuance of voluntary building standards and model codes. These standards and codes, in turn, are adopted widely by State and local building regulatory agencies. NEL has participated in many investigations of structural performance; such investigations help determine the probable cause for specific collapses and other building failures, while giving NBS and others an opportunity to learn more about structural performance so the building design criteria and measurement methods can be improved.

At the request of the U.S. Occupational Safety and Health Administration (OSHA), NEL researchers investigated the March 1981 collapse of the Harbour Cay Condominium in Cocoa Beach, Florida. The five-story, flat-plate reinforced concrete building collapsed while under construction, killing 11 workers and injuring 23 others. After conducting onsite technical investigations, laboratory tests, and a variety of analytical studies, the researchers concluded that "the most probable cause of the failure was insufficient punching shear capacity in the fifth floor slab to resist the applied construction loads." Punching shear capacity refers to the strength of the connection between the floor slab and the supporting columns.

NEL and NML investigators also determined the most probable cause of the July 1981 collapse of two walkways in the Kansas City Hyatt Regency Hotel, which killed 114 people and injured over 200. The study, which was conducted at the request of the mayor of Kansas City and members of the Missouri congressional delegations, concluded that critical connections in the walkways were capable of supporting less than one-third of the load expected to be carried by a connection designed under the Kansas City building code.

The investigators found that the connections as initially detailed and approved for construction provided a capacity far below that which would have been required to satisfy the building code. In addition, a change in the supporting hanger rod arrangement essentially doubled the load to be transferred by the connections, thus further aggravating an already critical situation.

And, also at the request of OSHA, researchers undertook an investigation into the most probable cause of the collapse of a highway bridge ramp in East Chicago, Indiana, which killed 13 workers and injured 17 others.

Investigations by NBS of structural collapses as part of the construction safety research program have shown a need for improved test methods for determining the strength of structures. We are currently working on this problem. A uniform set of probability based-load criteria developed in conjunction with the American National Standards Institute will be used for the design of all types of structures resulting in simple, less costly design procedures and safer, more economical structures.

Under the National Earthquake Hazards Reduction Program, which was established in response to the Earthquake Hazards Reduction Act of 1977, NEL gives technical support to the development of seismic design and construction provisions for buildings in the private and public sectors and conducts research on performance criteria and supporting measurement technology. For example, NEL participates in the Interagency Committee on Seismic Safety in Construction (ICSSC), which was formed to develop guidelines to assist Federal agencies involved in construction in reducing earthquake hazards. NEL has published the Draft Seismic Standard for Federal Buildings called for in the national program developed by ICSSC.

NEL has also published 11 reports for the Building Seismic Safety Council (BSSC), which was formed by NEL and the Federal Emergency Management Agency. The BSSC reports reviewed and refined the tentative seismic provisions for use in trial building designs and provide the basis for the development of recommended seismic provisions. Other NEL earthquake research is addressing the development of measurement and test methods to ascertain the potential for soil liquefaction in earthquakes and of a means to predict the strength and energy-absorbing capacity of masonry structures in earthquakes.

Through work sponsored in part by the Department of Energy and at the request of the Federal Trade Commission, NEL has recently made available calibrated samples of thermal insulation. Using a specially designed, high-precision, guarded hot plate, NEL engineers produced calibrated thick insulation transfer specimens in thicknesses of 25, 75, and 150 mm (1, 3, and 6 inches). The transfer specimens are being distributed for use in conjunction with the "representative thickness" provision of the Federal Trade Commission rules on "Labeling and Advertising of Home Insulation."

These samples should help ensure that competing firms make comparable measurements in determining the R-value (thermal resistance) of their insulation and that consumers will actually get the R-value advertised on the product. Previously, insulation manufacturers had to calculate the R-value of thicker insulation from measurements made on a tested thin insulation sample. However, the accuracy of the calculated R-values was not known because no reference samples of thick, low-density insulation that could be used to calibrate testing equipment existed.

# National Measurement Laboratory

SCIENTISTS and engineers of the National Measurement Laboratory (NML) perform research in many scientific disciplines covering a broad range of applications. The ultimate aim of their research is to assure that technological development is not hindered by a lack of accurate physical or chemical measurement standards and, especially, to provide the basic measurement technology needed to support advanced scientific fields of critical importance to the Nation.

Some examples of NML research achievements for fiscal years 1981 and 1982 are described below.

## *Improving Materials Processing*

NML's work in materials processing provides industry with the measurements, data, standards, and new conceptual understanding needed to improve process quality control and productivity, conserve energy, and develop advanced materials. NML develops basic concepts relating processing conditions, structures, and properties. These concepts are often expressed as models to support development of improved materials or improved use of materials. For example, a fracture map has been completed for silicon carbide, which is a possible replacement for superalloys at high temperatures. This map, built up by combining the results of theory and experiment, predicts the mechanical behavior that can be expected under various combinations of temperature and load conditions.

NML also operates a number of centers which compile and evaluate data from published technical papers and develop predictive techniques for important physical and chemical properties. In a major extension of a successful 4-year program, NML, the National Engineering Laboratory, and the American Society of Metals (ASM) have embarked on a worldwide program to gather, evaluate, store in computers, and disseminate alloy phase diagrams. These diagrams are "road maps" or "blueprints" used by metallurgists and engineers in selecting, designing, and processing alloys. They graphically represent the thermodynamic relationships among different metals in alloys and are used to understand and predict the alloys' structure at different temperatures or pressures.

Reliable phase diagrams are important to a variety of jobs, including finding substitutes for and recycling scarce metals, devising smelting and refining processes to make the most efficient use of metallic ore, and selecting materials for use in harsh environments or in critical applications. ASM estimates that the lack of the computer-readable, critically-evaluated phase diagrams costs U.S. industry and consumers many millions of dollars each year. The society has mounted a major fundraising drive for the expanded NBS/ASM program and expects that the program will be self-sustaining within about 4 years through the sale of phase diagram information services. More than $4 million has been pledged to the effort by industrial firms.

In the future, rapidly solidified alloys may replace other materials in many applications. Rapid solidification involves freezing liquid metals or alloys at rates as fast as a million degrees per second to achieve supercooling prior to solidification. By solidifying metals so quickly, new alloys can be formed with more refined and homogeneous structures having improved characteristics such as greater strength and lighter weight. NML is identifying concentrations and solidification velocities favoring particular microstructures and desired properties. This will aid researchers in predicting the microstructures that result from specific conditions and in developing industrial processes for improved alloys.

Composite materials, in which reinforcing fibers are bound together in layers by a polymer, are seeing increasing use. New carbon fiber composites are particularly important in the aerospace industry where tough, lightweight materials are in demand. Delamination, the growth of cracks between the layers of fibers, is a problem, however, in applications where the materials are subjected to loading or other stresses. In cooperation with the National Aeronautics and Space Administration, the University of Illinois, and a number of industrial laboratories, NML is studying the resistance of fiber-reinforced polymer composites to fracture and delamination. The researchers are designing measurement methods that can be used to evaluate the fracture resistance of the polymer matrix under various conditions.

Mixing polymers is one of the most rapidly growing and inexpensive techniques for producing polymeric materials with new properties. During processing, however, many of these polymer blends separate into phases of different compositions, adversely affecting their physical properties. The causes of phase separation are not well understood, hindering their industrial development. NML scientists are working with researchers from several industrial laboratories to develop measurement methods, data, and general theoretical descriptions of phase behavior in blends. Their theoretical work has already established the underlying thermodynamic basis for phase diagrams of some polymer blends, which are markedly different from those of other materials.

In another area of polymer research, scientists have developed a new dental restoration technique. The new process requires less drilling than other techniques, reduces treatment time, and increases patient comfort. The procedure permits bonding of plastic filling materials to the hard tooth tissues—enamel and dentin. With current clinical techniques it is only possible to bond the filling materials to the tooth enamel. Developed by the American Dental Association's Health Foundation research unit at NBS, the procedure calls for the application of some compounds not previously used in dentistry. A ferric oxalate solution is used to change the surface atoms in the enamel and dentin and then two surface-active monomers are applied to adhere the composites to them. The American Dental Association is coordinating biocompatibility testing of these materials prior to clinical trials.

## *Studying Surface Properties*

The study of surface atoms or molecules of a material is a rapidly developing field important in many areas of science and technology including catalysis, corrosion prevention, semiconductor devices, and communications. NML researchers and others are developing new experimental and theoretical tools to probe and understand at fundamental atomic and molecular levels, the physics and chemistry of complex surface processes. Some of these tools are already used in industrial and university research laboratories to study catalysts. For example, multipurpose chambers pioneered in NML for monitoring surface reactions are now available as commercial instruments.

The arrangement and kinds of atoms on the surface of an alloy play a critical role in its behavior as a catalyst and in the way it will bond to other metals. Knowledge of the changes in energy that take place in an alloy when one of its components migrates to the surface (called the heat of segregation) can help metallurgists select the best alloy for various industrial applications. But such thermodynamic properties have been difficult to measure accurately. An NML researcher has demonstrated a new method—based on the x-ray photoelectron spectra of alloys—that can be used to determine these properties with accuracy and ease. With this technique, it is possible to relate shifts in the core-level binding energies of atoms in binary alloys to such important thermodynamic values as the heat of segregation of an alloy's components. This technique is still experimental, but the accuracy with which heats of segregation can be determined (for copper-nickel alloys in particular) appears to be extremely high.

Techniques developed by NML scientists to probe the magnetic characteristics of the outermost atomic layers of ferromagnets are stimulating new theoretical and experimental investigations of surface magnetism. Researchers from NML and the Swiss Federal Institute of Technology have answered a fundamental question about surface magnetism that has eluded experimental investigators for 15 years. Using a technique called spin-polarized low-energy electron scattering, they measured the effect of surface magnons—long-wavelength surface spin waves—on the surface magnetization of a ferromagnetic material. Their results proved an earlier theory that surface magnetization would follow Bloch's law just as bulk magnetization does (that is, as temperature increases, surface magnons would decrease surface magnetization and increase the surface specific heat), but a key coefficient was found to be about 50 percent greater than originally theorized.

As a byproduct of their research into chemical processes, NML researchers have patented an idea that may lead to an improved method of removing sulfur dioxide—and, possibly, nitrogen oxides—from industrial gas streams such as flue gas from fossil fuel power plants. At present, sulfur dioxide is removed from exhaust gases by circulating the gas through a slurry of powdered limestone suspended in water, a process called "scrubbing." The process is messy and the equipment tends to plug with residue. Moreover, the end product is a precipitate that has minor commercial uses but usually winds up being buried in industrial waste sites.

While there is a large gap between the reaction scheme proposed by the NML chemists and a successful commercial process for cleaning sulfur out of industrial waste gases, their research does suggest some alternatives to present methods. The proposed reaction chain involves only gases, which could avoid the plumbing problems caused by slurries. In addition, the sulfur dioxide and nitrogen oxides are converted to sulfuric acid and nitric acid mists, which can be readily removed with existing methods and converted to solid ammonium nitrates and sulfates, basic components of commercial fertilizers. This reaction chain also produces a combustible, sulfur- and nitrogen-free hydrocarbon that could be commercially useful, or at least easily destroyed. If successfully developed, this process would allow power plant operators, for example, to burn almost any fuel, including cheap, high-sulfur coal, without any pretreatment.

## *Expanding the Measurement Frontier*

The demands of our highly technical society for increasing measurement accuracy have resulted in a need for more sophisticated standards. And the development of these standards requires an ever deepening understanding of the physical world.

One of the biggest obstacles to improving the resolution of laser spectroscopy and the precision of atomic clocks and frequency standards is the Doppler broadening and shifting of atomic and molecular resonances, an effect caused by the velocity of the atom or molecule being observed. NML researchers have attacked this problem with the aid of carefully tuned laser beams that slow down, or "cool," oncoming atoms or molecules. To do this, NML scientists have isolated the particles from perturbing influences by suspending them in an electromagnetic "trap" and then lowering their temperature.

Such devices can be used to study thousands of ions or a single particle, cooling them to near absolute zero. The ability to deal with particles in a relatively undisturbed state could permit the development of time and frequency standards that are 100 times better than those presently available and lead to a significant improvement in ultra-high resolution spectroscopy.

Electromagnetic traps will hold only ions—charged particles—however, so other NML researchers have studied the problem of cooling a stream of neutral atoms. They succeeded in what is believed to be the first definitive experiment to slow down a stream of neutral atoms in the beam of a cooling laser. The NML researchers used the Zeeman effect in which the energy levels of quantum states are shifted in magnetic fields. Their success depended in part on the invention of a special solenoid which was used to create a gradually changing magnetic field along the path of the neutral atoms, keeping them "in tune" with the opposing laser beam.

In some of the most precise chemistry experiments ever, NML researchers have measured the atomic weight of silver to the unprecedented accuracy of about 0.5 part per million (ppm), a fivefold improvement on the best previous measurement. This work, combined with previous experiments by other NML researchers to determine the electrochemical equivalent of silver, yielded a new value for the Faraday constant estimated to be accurate to 1.4 ppm, a measurement five times as accurate as the best previously directly measured value.

The Faraday constant relates the amount of electricity used in a chemical reaction to the amount of substance reacted. A fundamental constant of nature, the Faraday is linked directly to a number of other important constants, including the proton mass, the proton gyromagnetic ratio, the proton magnetic moment, and the Avogadro constant.

As a result of this work, NML researchers demonstrated a significant discrepancy between the value of the Faraday as determined by an electrochemical experiment and the value as calculated from related fundamental constants. This reinforced previously observed discrepancies between the calculated and experimental values for the Faraday. The implication is that other values in the interrelated circle of constants that includes the Faraday are less accurate than previously thought. Researchers are now looking at the experimental values for both the ampere and Avogadro's constant as possible sources of the disagreement.

Applying metrology to geophysics, scientists at the Joint Institute for Laboratory Astrophysics (JILA), a research group operated jointly by NBS and the University of Colorado, are making measurements that have direct bearing on the study of earthquakes and may lead to more accurate earthquake prediction. JILA scientists are using two very different methods to measure g, the acceleration due to gravity. The first is based on an instrument called a falling corner cube gravimeter which measures g with an accuracy of 6 parts per billion. This is equivalent to detecting changes of 4 centimeters in the distance from the surface to the center of the earth. Such measurements permit detection of long-term crustal movements and mass motions below the earth's surface. It is believed that these motions may be associated with the buildup of stress before earthquakes.

In the second method, relative gravimeters and tiltmeters are used to measure extremely small changes in the value of g or in the angle between the direction of g and a line perpendicular to the earth's surface. Tidal distortion of the solid earth causes the value of g to go through a daily cycle. The amplitude of this change, equivalent to a change of about 30 centimeters in the distance from the earth's surface to its center,

can be measured to 1 ppm; changes in the direction of g can be measured to a billionth of a degree. By comparing such measurements with theoretical predictions, scientists can study the elastic properties of the earth, and, in particular, any changes in these properties that may be related to changes in the earth's crust. JILA scientists are currently installing an array of ten tiltmeters at Yellowstone National Park to study the elasticity of the molten rock beneath the surface in some areas of the park.

## *Developing New Measurement Techniques*

NML scientists have developed and installed a new research facility designed to expand NBS and U.S. capabilities for neutron scattering studies of microscopic structures in materials. The new facility performs measurements at smaller scattering angles (thus allowing studies of large structures) and with data rates up to 100 times faster than the instrument that it replaces at the NBS reactor. This enhances the ability of researchers to study the microstructure of materials such as metals, glasses, magnetic materials, polymers, and biomaterials. Small angle neutron scattering (SANS) is a nondestructive technique with a diversity of applications ranging from the study of density variations in alloys or other structural materials to the determination of the size and shape of large molecules such as polymer chains or proteins.

While instruments with similar capabilities have been in operation in Europe for several years, NBS is one of only a few research institutions in this country with SANS facilities. The increased measurement capability of this facility is a result of a combination of several developments: a novel beam collimator; the use of a 65-centimeter-square area detector linked to a computerized, color-enhanced display system; and the availability of continuously variable neutron wavelengths incident on the samples. Like other facilities at the NBS reactor, the new SANS facility is available for use by industry, university, or other government researchers working on cooperative projects with NML scientists.

Highly "pure" specialty materials, such as superalloys or electronic materials, may be rejected in production or fail in service due to defects introduced by small amounts of very localized impurities. Similarly, certain dangerous chemicals or toxic metals may concentrate on the surface of small, respirable particles or in specific organs of plants or animals. In such cases, researchers need to know the exact distribution of molecules and atoms.

NML scientists are working on analytical methods employing primary beams of electrons, ions, or photons and detecting as signals the x-rays or scattered photons produced during interaction with the sample. These techniques can be used to prepare "area maps," which plot lateral distributions, and depth profiles of elemental or molecular constituents. In addition to providing the basic information needed for relating composition and behavior, these compositional maps also reveal information on the formation and likely origins of materials—whether a particle is manmade or natural, for example.

Another technique developed by NML scientists could help industrial chemists solve a longstanding measurement problem—how to determine quickly and accurately the extent of PCB, or polychlorinated biphenyl, contamination in lubricating and cooling oil samples. PCB's were used extensively as coolants in electrical systems until their manufacture was banned in 1979 by the Environmental Protection Agency (EPA) for most applications. PCB's physically resemble lubricating oils and have frequently been added mistakenly to oil stocks destined for recycling.

The NML researchers combined gas chromatography with high-performance liquid chromatography (HPLC) to achieve detection sensitivities of better than 1 ppm. Major interfering components in an oil sample are first selectively removed with HPLC, and the "clean" sample is then separated into its components using a wall-coated, open-tubular gas chromatographic column. Other techniques for analyzing PCB's involve extensive sample preparation, are time consuming, and can often produce ambiguous results.

## *Ensuring Measurement Accuracy*

NML researchers are also working on a Standard Reference Material (SRM) that will consist of separate solutions of two commercial PCB mixtures, one each in a transformer oil and a motor oil base. The new SRM should

be useful to the electrical industry, the oil recycling industry, and environmental monitoring organizations for calibrating analytical PCB monitoring procedures.

SRM's, produced by NBS since 1906, play a major role in increasing and ensuring the accuracy of measurements. Reliable measurements can help avoid costly manufacturing mistakes and unnecessary overdesign of products and systems; they can provide the basis for sound and economical environmental and safety regulations; and they can improve health care by increasing the validity of clinical tests and procedures.

NBS recently issued an urban dust SRM that is the first air particulate material to be certified by NBS for the concentration of selected polynuclear aromatic hydrocarbons (PAH's), such as compounds from engine combustion and burning fuels. Many of these PAH's have been found to be carcinogenic and have been identified as priority pollutants by EPA.

In addition, NBS has made available a human serum SRM. It was developed for use in assessing the accuracy of clinical methods that measure certain constituents in human serum, calibrating instrumentation used in these analyses, and validating in-house or commercially produced quality control materials.

And, in an effort to ease the shortage of high-accuracy standard gas samples used in calibrating pollution measurement instruments and methods, NML and EPA developed a procedure to allow commercial gas suppliers to produce certified reference materials (CRM's) that are traceable to NBS SRM's. The procedure provides for the production by specialty gas companies of standard gas mixtures (such as carbon monoxide in air) according to protocols specified by NBS and in accordance with a quality control program audited by EPA. The use of CRM's will be accepted by EPA as meeting ambient air and stationary source emissions regulations that require gas standards to be "traceable to NBS Standard Reference Materials."

Working with the U.S. Nuclear Regulatory Commission, NML scientists have designed and built a new calibration source for testing neutron personnel dosimeters and protection instruments. Because it is sometimes necessary for workers to enter a reactor containment area while the reactor is operating, measuring a neutron dose received by the workers is a vital part of radiation protection programs. When dosimeters were calibrated using conventional procedures, they gave results that were too high by a factor of 30. With the new NML calibration source that factor is reduced to 1.5. The new source, a 30-centimeter sphere of heavy water surrounding a Californium-252 fission neutron source, is now being copied at several U.S. and European laboratories and is being written into both the latest American National Standard and International Standard for testing personnel dosimeters.

In an expansion of the Bureau's services in electrical measurements, NML has begun a regional measurement assurance program through which companies in the New York City-New Jersey area can check the accuracy of their voltage measurements. The defense, aerospace, electrical instrumentation, and independent calibration laboratory communities use these services to ensure the accuracy of their electrical measurements necessary to new product development and production quality control.

In regional measurement assurance programs, the client's complete measurement system, not just an instrument, is "calibrated." A stable, well-characterized "transfer standard" and a description of appropriate measurement techniques are sent from NBS to one of the participating laboratories. The laboratory makes measurements on the standard and compares its measurements to those made at NBS. The transfer standard is then circulated to the other laboratories in the group and, finally, returned to NBS for remeasurement. NBS and the participating laboratories then analyze the data and work together to eliminate any problems found in the laboratories' measurement systems.

# Institute for Computer Sciences and Technology

THE efficient and economical use of computers—along with the related information technology—presents a major challenge to industry and Federal, State, and local governments. Large and complex computer systems must operate reliably and securely to protect the sensitive and valuable data and personal information they contain from abuse, theft, sabotage, and natural hazards.

With a program designed to improve the management and use of information technology, the NBS Institute for Computer Sciences and Technology (ICST) provides Federal agencies with scientific and technical services in the area of automated data processing (ADP), recommends uniform Federal ADP standards, and conducts the necessary supporting research. For the past few years, ICST has addressed critical ADP-related problems: rising software costs; incompatibilities among system components, systems, and networks; vulnerable computer data and resources; and user needs for guidance in selecting and applying information technology. Federal Information Processing Standards (FIPS) issued by ICST are designed to help improve productivity in the Federal government through more efficient procurement, management, and use of its computer resources.

ICST works closely with industry and Federal, State, and local governments to determine standards needs. ICST computer scientists meet regularly with the Information Technology Strategic Group, a group of senior management officials which advises ICST on its programs and which represents over 95 percent of Federal information processing resources. Partly as a result of this interaction, ICST has modified its program plan to include the development of guidelines and information reports that are needed for ADP planning and software management. User needs in data management and database management are the chief concerns of the Federal Data Management Users Group, recently organized by ICST. ICST also communicates regularly with State and local government representatives and with other groups of Federal officials such as the internal auditors who are responsible for ensuring that public funds are put to the best possible use.

ICST develops standards in cooperation with both national and international voluntary industry standards groups whenever possible so that Federal standards will be compatible with industry standards. Prototype standards are tested in cooperation with industry and government organizations. ICST collects and analyzes data on technology trends and the costs, benefits, and impacts of standards.

In efforts directed toward the efficient and effective management of computers and information processing, ICST provides scientific and technical advisory services to other Federal agencies. These services include studies of technical feasibility, assistance in design and selection of systems, evaluation of systems, and development of special information processing techniques. For example, ICST helped the Federal Bureau of Investigation by developing procedures for automatically identifying and matching fingerprints, assisted the Naval Air Development Command in assessing the state-of-the-art of speech recognition systems, and advised the National Institutes of Health on a long-term project to microrecord medical records.

## *Facilitating Networking*

ICST is giving high priority to the development of standards to improve the interoperability of computers and components. Without common, accepted processes for transmitting and receiving information between parts of a system or between systems in a network, equipment cannot be linked into compatible systems, and networks cannot be developed from commercially available products. This lack of compatibility and interoperability hampers computer users who want to tailor systems to meet their specific needs.

For example, to take full advantage of public data networks, satellite networks, local area networks, and computer-based office systems, computer users need standard protocols that operate over a variety of communication technologies. But such standard protocols are not available. As a result, users cannot easily transfer files, execute jobs remotely, send electronic messages, or communicate graphics information through heterogeneous networks.

ICST is developing specifications for computer network protocol standards that represent the first steps toward the full and cost-effective integration through networks of the different equipment available. When the complete set of planned network standards is issued, agencies will be able to develop computer networks using off-the-shelf network products, and manufacturers will not have to design expensive, unique networks for different customers.

Because these efforts will not be successful without consensus among manufacturers and users, NBS computer scientists are working closely with such national and international organizations as the International Organization for Standardization (ISO), the Network Users Association, the Consultative Committee for International Telegraph and Telephone, the American National Standards Institute (ANSI), and the European Computer Manufacturers Association. ICST's proposed protocols are patterned on ISO's Open Systems Interconnection reference model and specify functions to support communications and data processing through networks. Specifications have been completed for the transport function that provides the reliable and in-sequence delivery of data across (within) a computer system, which is necessary in almost all network communications. The dialogue and data management services are covered in the session protocol, which is also completed. Under development is the file transfer/data presentation protocol that will aid in file transfer, terminal access, computer-based messaging, and remote job entry.

After the proposed protocols are reviewed, formal proposals of the protocols as Federal standards will be put together. During this phase, the protocols will be tested by NBS and a number of other organizations that have expertise in the design, implementation, and testing of computer network protocols.

To test and evaluate prototype protocol implementation, ICST has developed a network protocol laboratory that will be used to ensure that the protocols work accurately and adequately in different environments. ICST has made this facility available via government and commercial networks so users and vendors can test protocols themselves.

As another part of its effort to facilitate the connection of computers and terminals to networks, ICST, in cooperation with the National Communications System, has announced a proposed joint FIPS and Federal Standard (FED STD) for interconnecting computer systems to public data networks. The joint standard was based on X.25, "Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Terminals Operating the Packet Mode on Public Data Networks," as adopted by the International Telegraph and Telephone Consultative Committee of the International Telecommunications Union.

Approval is expected for another FIPS that covers the format and content of messages exchanged between computer-based message systems. This proposed standard, the first FIPS developed for office systems, will enable users of message systems of widely varying design and complexity to send messages to each other. Supported by leading suppliers of electronic mail software and services, the format standard consists of data elements and fields that will facilitate the transmission of electronic mail between otherwise incompatible networks.

## *Using Database Management Systems Effectively*

ICST's computer scientists are also giving high priority to the development of standards and guidelines that will permit economical use of flexible software systems that format, store, manipulate, and access the government's large databases. Called database management systems, such systems offer significant benefits in centralizing data collection, reducing duplicate files, and providing users, especially non-technical users, with easy access to shared information.

While estimates of the number of Federally-owned database management systems range from about 500 to over 3700, there is agreement that the Federal government has a large investment in a wide variety of database management systems and that these systems will fill an increasingly large role in data processing. A survey done by ICST showed that ADP managers were pleased with the power, flexibility, and cost effectiveness of database management systems. However, the major benefits of a database management system are increased versatility and productivity, not reduced costs.

ICST is presently working on guidelines and standards that will permit more effective use of data files and enable personnel to move from one system to another without extensive retraining. A proposed architecture for database management standards, developed under ICST direction, has been circulated to government agencies, commercial vendors, independent consultants, and other interested parties for comment and review. The generic architecture for a database management system is designed to unify the wide variety of functions and components of database management systems. It is based on several key features including the comprehensive identification of database management system functions, the grouping of these functions into components, the support of multiple data model standards, and the specification of both internal and external interfaces. Each of these key features should contribute to the development of effective database management system standards.

Another guideline issued by ICST provides explicit advice on achieving database integrity and security control. Published as FIPS publication 88, "Guideline on Integrity Assurance and Control in Database Administration," the guideline documents a step-by-step procedure for examining and verifying the accuracy and completeness of a database. The guideline suggests methods for assuring the proper operation of controls designed to prevent, detect, correct, or reduce the possibility that the computerized data in the database can be altered or destroyed either accidently or maliciously.

## *Improving Computer Security*

With the increases in the number of networks and database management systems, providing adequate security for the information stored in these systems becomes a major challenge to Federal agencies. ICST computer scientists are working on procedures that ADP managers can use to assess and deter threats to their computer resources, to assure that only authorized users have access to computer systems and data, to audit ADP processes for possible misuse, and to assure data integrity. The standards and guidelines will cover: techniques and methods to control access to computer networks, data encryption to protect information in transmission between computers, physical security measures, and controls for applications systems.

As part of this program, ICST has issued "Guidelines for Implementing and Using the NBS Data Encryption Standard" (FIPS PUB 74), which is to be used by Federal agencies when they decide that cryptographic protection is required for sensitive or valuable computer data. These guidelines are to be applied in conjunction with the "Data Encryption Standard" (FIPS PUB 46) issued by NBS in 1977 and with the recently published "DES Modes of Operation" (FIPS PUB 81).

The Federal Data Encryption Standard (DES) specifies a cryptographic algorithm for the cryptographic protection of sensitive, but unclassified, computer data. Originally developed for Federal use, the Data Encryption Standard has been adopted as a voluntary industry standard and is being used by the banking community to protect electronic funds transfers. The standard "DES Modes of Operation" describes four ways in which the DES may be used in a wide variety of applications to encrypt (cryptographically protect) and decrypt (return to original form) data. The modes covered are: Electronic Codebook mode, Cipher Block Chaining mode, Cipher Feedback mode, and Output Feedback mode. The standard specifies the numbering of data bits, the way bits are encrypted and decrypted, and the data paths and data processing necessary for encrypting and decrypting data or messages.

The new guidelines (FIPS PUB 74) present factors that should be considered when cryptographic or key management schemes are implemented. With improper implementation and use, data encryption may provide only an illusion of security. With inadequate understanding of encryption techniques, data managers may not recognize the need for other protection techniques. However, with proper management controls, adequate implementation specifications, and applicable usage guidelines, data encryption will not only aid in protecting data communications but can provide protection for a myriad of specific data processing applications. These guidelines also describe a number of implementation techniques.

While security measures are employed to prevent or detect accidental or intentional disclosure, modification, or destruction of data or loss of the means of processing those data, contingency plans are also necessary to minimize the damage caused by unexpected and undesirable events in and around ADP facilities. "Guidelines for ADP Contingency Planning," FIPS PUB 87, describes what ADP managers should consider when developing a contingency plan for an ADP facility. Although a recommended plan is not given, the guideline does suggest three elements that any contingency plan for a data processing activity should contain. The first is emergency response procedures necessary to protect lives, limit damage, and minimize the effect on data processing operations in case of fire, flood, civil disorder, natural disaster, bomb threat, or any other incident or activity. Backup operations procedures are also needed to ensure that essential data processing tasks can be conducted after operations at the primary data processing facility have been disrupted. And, each plan should contain recovery procedures to facilitate the rapid restoration of a data processing facility following physical destruction, major damage, or loss of data.

As a companion to this guideline, ICST recently issued an "Executive Guide to ADP Contingency Planning," which is intended for executives and managers who depend on ADP resources, but who may not be directly responsible for the daily management or supervision of data processing activities or facilities. This executive guide contains the background and basic information they need to understand how ADP contingency plans are developed.

## *Revising COBOL*

ICST also produces high level programming language standards and guidelines that are designed to improve productivity of computer programmers, ease conversion of programs written for one system to use on other systems, encourage transportability of both programs and programming skills, make program modifications easier, and enhance documentation and program testing.

ICST computer scientists are now working with an ANSI committee and Federal computer users to revise the American National Standard COBOL. After evaluating user comments on and doing its own analysis of a proposed revision, ICST recommended that the proposed version be modified and an analysis of its effect on users be done. ICST is conducting its own study of the proposed revision's impact on Federal users and plans to share the results with the committee. As further changes are made, ICST will keep Federal users informed and represent their interests on the committee.

Federal Information Processing Standards Publications (FIPS PUBS) issued by ICST are produced to help improve the management and use of information technology. All FIPS PUBS are sold through the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. For information on FIPS PUBS, write to the Standards Processing Coordinator, B64 Technology Building, National Bureau of Standards, Washington, DC 20234.

# Services and Special Programs

THE National Bureau of Standards offers a broad range of services and opportunities for cooperative activity with Federal, State, and local governments, industry, universities, technical societies, voluntary standards groups, trade associations, international organizations, and the general public. Supplementing an informal, long-standing tradition of consultation with the public and private sectors, these efforts are designed to foster the widest possible transfer of science and technology from the Bureau to all scientific and technical communities. Listed below are some of these services and programs, along with information about how to obtain additional details.

## *Calibration Services*

The calibration of instruments and devices is an essential feature of the Bureau's mission to provide the basis for a complete and consistent national system of physical measurements. Each year NBS calibrates about 7,000 items ranging from ac voltage standards to x-ray and gamma-ray measuring instruments. About 80 percent of these calibrations are done for industry, especially those groups involved with product design, research, government procurement, production quality control, and testing. For example, one large U.S. photographic company relies on photometric and radiometric calibrations by NBS to generate 500 internal standards each year, which in turn are used to produce an annual sales volume of $5 billion. In another case, 60 NBS calibrations a year for the primary standards laboratory of a major U.S. instrument manufacturer support the company's measurement requirements for its research and development laboratory, for 10 of its technical service centers that repair and calibrate 18,000 instruments annually, and for the company's two manufacturing plants, which calibrate 75 percent of the instruments produced.

The Bureau's calibration services cover: mass and dimensional metrology; mechanics and acoustics; electrical measurements (dc and low frequency); electromagnetic measurements at radio, microwave, and millimeter wave frequencies; time and frequency; thermodynamic quantities; optical radiation measurements; and ionizing radiation. A complete description of these and related measurement services is provided in *Calibration and Related Measurement Services of the National Bureau of Standards*, NBS Special Publication 250. The catalog is available for $6 prepaid from the U.S. Government Printing Office, Washington, D.C. 20402; order by stock number 003-003-02446-5.

## *Standard Reference Materials*

Standard Reference Materials (SRM's) are well-characterized, homogeneous, stable materials or simple artifacts with specific properties measured and certified by NBS. Produced by NBS since 1906, SRM's are used widely throughout the United States and the world to help develop test methods of proven accuracy, to calibrate instruments and measurement systems used to maintain quality control, to help assure equity in buyer-seller transactions, and to assure the long-term reliability and integrity of the measurement process.

The Bureau currently has about 900 different SRM's available. For example, SRM's are used to establish reference points on the International Practical Temperature Scale, the scale to which all temperature measurements are referenced. The composition of 90 percent of the steel produced in the United States is controlled by measurements based on SRM's. SRM's help improve the accuracy of clinical measurements, including those of glucose, urea, and sodium, that are used by physicians to diagnose and treat disease. A series of gas SRM's provides the basis for accurate monitoring of automotive pollution and mileage testing.

Each year NBS sells about 40,000 SRM units to more than 10,000 customers around the world. SRM's serve major segments of industry including those specializing in ferrous and nonferrous metals, mining, glass, rubber, plastics, primary chemicals, nuclear power, electronics, automotives, and computer instrumentation. For more information on the NBS SRM program, write or call the Office of Standard Reference Materials, B311 Chemistry Building, (301) 921-2045.

## *National Standard Reference Data System*

The National Standard Reference Data System (NSRDS) gives scientists and engineers easy access to critically evaluated, reliable data on physical, chemical, and engineering properties of substances and materials. Such data are essential to the progress of science and the translation of scientific understanding into useful technology. Lack of reliable data for engineering design can result in costly overdesign or, possibly, catastrophic failure. In one case, it was shown that a 1 percent uncertainty in design data could increase the annual operating cost of a chemical plant by 10 to 15 percent.

A nationwide program, NSRDS is coordinated by NBS but involves many groups in universities, government laboratories, and private industry. Researchers at more than 20 NSRDS data centers, located at NBS and throughout the country, pull together the results from many diverse research activities, evaluate these data critically, and organize them in a more dependable and useful form. In fiscal year 1982, 4,360 pages of evaluated data were produced. The data are used by industry in engineering design, process control, and new materials development; by the Federal government in defense, the space program, environmental modeling, and long-range energy research and development; and by academia in research. For example, 50,000 scientists and engineers in chemical and petroleum industries use NBS-evaluated data.

The databases produced by this program are available in printed form, on magnetic tape, and through on-line computer services. In cooperation with the American Chemical Society and the American Institute of Physics, NBS publishes the quarterly *Journal of Physical and Chemical Reference Data*. Further information on this program is available from the NBS Office of Standard Reference Data, A323 Physics Building, (301) 921-2467.

## *Measurement Assurance Program Services*

A series of Measurement Assurance Programs (MAP) services developed by NBS assists laboratories in improving or verifying their ability to make accurate measurements. These measurement assurance services allow public or private laboratories to test their entire measurement system for accuracy relative to NBS. This is important because final accuracy of a measurement depends on more than the calibration of a measurement instrument. It also depends on the environment in which the instrument is used, the skill of the technician making the measurement, the measurement procedures used, and similar factors.

Decisions with significant economic consequences are frequently based on a measurement or series of measurements. For example, in industry inadequate quality control measurements may result in a "good" lot of items being rejected or a "bad" lot being accepted. In either case the costs associated with such incorrect decisions can be appreciable. Or a metrologist's organization could be a party to a lawsuit in which the accuracy of measurements is a central question. In such situations, a rigorous formal measurement quality assurance program including detailed documentation is essential.

MAP's provide the basis for statistical quality control procedures that industry can use to increase productivity and improve product quality. In setting up measurement assurance programs, NBS works with both individual laboratories and groups of laboratories, in which case the laboratories share the cost of the program. At present, NBS offers measurement assurance services in mass; electrical resistance, capacitance, power, and dc voltage; laser power and energy; and temperature. For further information, contact the NBS Office of Measurement Services, B362 Physics Building, (301) 921-2805.

## *Standards and Certification Information Service*

The NBS National Center for Standards and Certification Information (NBS-NCSCI) maintains a comprehensive reference collection of engineering and related standards. The NBS-NCSCI collection includes over 240,000 standards, specifications, test methods, codes, and recommended practices issued by U.S. technical societies, professional organizations, trade associations, State purchasing offices, Federal agencies, and foreign national and international standards organizations. The collection also contains reference books, articles, reports, newsletters, and microfilm files. The center answers over 5,000 inquiries a year on standards and standards-related subjects. Searches of the standards literature by NBS-NCSCI, with names of organizations where copies of the standards can be obtained, are available. Address requests (as specifically as possible) to the National Center for Standards and Certification Information (NBS-NCSCI), B166 Technology Building or telephone (301) 921-2587 or use Telex 89-8493.

In support of the Trade Agreements Act of 1979, the center also operates a "hotline"—(301) 921-3200—that exporters, producers, standards organizations, and others concerned with international trade can call for a recorded listing of proposed mandatory foreign standards and certification systems. The hotline reports on standards-related notifications from the Secretariat of the General Agreement on Tariffs and Trade in Switzerland.

## *Energy-Related Inventions Program*

To ensure that promising energy-related inventions receive a thorough, objective review—particularly inventions from individual inventors and small firms—the NBS Office of Energy-Related Inventions offers free evaluations. Established by the Federal Nonnuclear Energy Research and Development Act of 1974, the NBS program provides a way for anyone with a nonnuclear, energy-related invention to have a technical review of the device, material, process, and/or procedure. If the evaluation by NBS indicates that an invention shows significant promise for saving or producing energy, NBS recommends it to the Department of Energy (DOE), which will consider assisting the inventor in its development.

From mid-1975, when NBS opened its inventions evaluation office, through September 30, 1982, the Bureau received 18,412 requests for evaluations and recommended 221 inventions to DOE. For more information and an evaluation request form, contact the NBS Office of Energy-Related Inventions, A46 Technology Building, (301) 921-3694.

## *Research Associate Program*

The Research Associate Program enables scientists and engineers from industrial, professional, trade, and other organizations to work for specified periods at NBS, providing a unique mechanism for the transfer of technology. With their salaries paid by sponsoring employers and organizations, the associates work on a wide range of research, including automated manufacturing, fire safety, computer technology, and dental materials, of clear mutual interest to NBS and their sponsors.

Both NBS and the sponsoring organizations profit from this type of interaction. Research associates benefit from the use of NBS facilities and from the opportunity to do cooperative research with the diverse NBS professional staff. They then can take newly developed technology back to their organizations for prompt application. NBS gains from the program by learning firsthand the views and needs of the industrial community.

During fiscal year 1982, 121 research associates worked with NBS on 44 different projects. Of these approximately 60 percent were sponsored by private industrial companies and 40 percent by trade or professional organizations. More than 400 organizations and 1,000 individuals have participated in the program since it began in 1921. For additional information, write or call the Industrial Liaison Officer, A402 Administration Building, (301) 921-3591.

## *State and Local Liaison*

A significant portion of NBS activities addresses matters of substantial interest to State and local governments, such as the Bureau's measurement work in the areas of weights and measures, analytical chemistry, and radiation research. Also important is NBS research in the fields of fire prevention, building codes and standards, computers, and law enforcement. NBS works closely with such groups as the National Conference on Weights and Measures and the National Conference of States on Building Codes and Standards to ensure that the Bureau's programs provide the measurement foundation needed by State and local officials concerned with equity and safety in the marketplace. To further the effective transfer of these technologies to their appropriate users, the NBS Office of State and Local Governmental Affairs serves as a point of contact for representatives of State and local governments. For information, write to the Liaison Officer, State and Local Governmental Affairs, A402 Administration Building, (301) 921-3814.

## *Guest Worker Program*

NBS also has a Guest Worker Program that brings researchers to the Bureau to work on specific projects as a way of providing better dissemination of NBS research directly into user communities. The program permits specialists to work with NBS staff on projects of mutual interest for periods of several months up to 2 years. Last year foreign institutions and governments, international organizations, and U.S. groups sponsored 144 scientists and engineers from 31 countries and 162 domestic guest workers who collaborated with Bureau researchers in such areas as materials, fire, and building technology. Interested researchers from abroad should contact the NBS Office of Inter-

national Relations, A511 Administration Building, (301) 921-2463, which will coordinate necessary clearances with the U.S. Department of State. U.S. researchers should contact individual NBS divisions or centers directly.

## *Postdoctoral Research Associate Program*

Each year the NBS Postdoctoral Research Associate Program enables about 50 postdoctoral scientists and engineers of unusual promise and ability to conduct research at NBS on problems that are compatible with Bureau interests and contribute to the overall NBS research effort. Operated in cooperation with the National Research Council, the program is intended to be analogous to fellowships, associateships, and other temporary programs at the doctoral level in universities. Further details may be obtained from the Chairman, Postdoctoral Research Associate Program, A113 Materials Building, (301) 921-2103.

## *Information Services*

In fiscal year 1982 NBS received about 40,000 requests from the public for information on Bureau publications and research activities. If you are interested in more detailed information on the Bureau's research program in any area, you may write to: NBS Inquiry Service, A537 Administration Building, or call (301) 921-2318.

NBS also has a media liaison group to help reporters obtain information on the Bureau's research activities. This unit answers over 1,000 inquiries every year from newspaper, magazine, and radio and television reporters. Journalists can contact the Media Liaison Office, A903 Administration Building, or call (301) 921-3181 for detailed information about NBS and its activities. For information on the Bureau's Boulder Laboratories, write to the Program Information Office, 4001 Radio Building, National Bureau of Standards, Boulder, CO 80303, or call (303) 497-3244.

From its early days, NBS has been a gathering point for the exchange of ideas and information. Scientists and engineers from across the country and around the world, representing every discipline embraced by the Bureau, come to attend major scientific conferences; special seminars; and small, informal meetings and lectures. Each year NBS sponsors or cosponsors about 90 conferences and workshops that are attended by about 14,000 participants. Such meetings are an important opportunity for Bureau researchers to stay abreast of the latest developments and needs in their fields, and for other participants to become familiar with work done at NBS. Information on upcoming conferences and meetings at NBS can be obtained from the Special Activities Office, (301) 921-2721.

Professionals and interested members of the public should also be aware that NBS has produced a variety of audiovisual products—films, videotapes, and slide-audio shows—that describe the results of particular research projects. Subject areas include building technology, robotics, automation technology, safety, fire research, electronic technology, computer science, chemistry, materials science, measurement techniques, and dental research. For more information, write: Audiovisual Products and Services, A903 Administration Building, or call (301) 921-2721.

NBS also keeps its audiences informed through the use of special exhibits at conferences, trade shows, science centers, and similar events. From October 1980 through October 1982, NBS sponsored exhibits that were viewed by more than 615,000 people.

## *Publications*

NBS publications are among the most important conduits through which the Bureau shares the results of its research and studies with its many audiences. Fourteen categories of publications, including the *NBS Journal of Research*, handbooks, and monographs, are issued. During fiscal year 1982, NBS published 1,531 papers in NBS publications and external journals. For a complete annual list of NBS publications, write the U.S. Government Printing Office for *Publications of the National Bureau of Standards*, NBS SP 305, Supplement 13. The catalog is available for $12 prepaid; order by stock number 003-003-02400.

# Resources

THE work described in this report is carried out by the Bureau's highly skilled staff who are often recognized as national or international leaders in their specialities. Over the past 2 years, the size of the permanent staff has been reduced from about 3,100 to approximately 2,665 full-time employees. In Gaithersburg, Maryland, located north of Washington, D.C., NBS has about 2,280 full-time employees working in 26 buildings on 230 hectares (575 acres).

The Bureau also has nearly 385 full-time staffers who work in 14 buildings on 83 hectares (208 acres) in Boulder, Colorado. The Joint Institute for Laboratory Astrophysics, cosponsored by NBS and the University of Colorado, is located in Boulder, where scientists study atomic and molecular physics and astrophysics. At Ft. Collins, Colorado, NBS operates radio stations WWV and WWVB, which broadcast standard time and frequency information. Another station, WWVH, broadcasts from Kauai, Hawaii.

As the Nation's central reference laboratory, the Bureau houses a number of special facilities and equipment, many of which are available for use by the scientific and engineering communities. A high flux nuclear research reactor is used daily by scientists from NBS, other agencies, and universities in projects ranging from nuclear theory to analysis of food contaminants. A new facility designed to expand NBS and U.S. capabilities for neutron scattering studies of microscopic structures in materials was recently installed at the NBS reactor. The research tool—called a small angle neutron scattering facility—performs measurements at smaller angles (thus allowing studies of larger structures) at data rates up to 100 times faster than the instrument it replaced.

An electron accelerator, capable of producing well-focused electron beams of 140 million volts, is used to produce high-energy electrons, positrons, photons, and neutrons for nuclear research. Another facility, the Synchrotron Ultraviolet Radiation Facility (SURF II) is the Nation's most accurately known source of ultraviolet and soft x-ray radiation. As a result of changes to the magnetic field booster and correction coils, SURF II can now handle electron energies up to 275 MeV and will be extended to 280. SURF II is a unique calibration facility used in studies of controlled nuclear fusion and atmospheric science programs.

Among other NBS facilities are a fire research laboratory, an experimental computer facility, and several environmental chambers. In addition, an extensive instruments shops group answers specialized research needs. Shop capabilities include glass blowing, optics, and metalworking.

In fiscal year 1981, the Bureau operated on a budget of $172.1 million. Direct Congressional appropriations accounted for about 62 percent of NBS' fiscal year 1982 budget of $172.9 million, with an additional 31 percent resulting from work performed by NBS for other government agencies. The sale of NBS goods and services, such as Standard Reference Materials and calibrations, provided the final 7 percent.

## Total NBS Operating Funds — All Sources

*(in millions of dollars)*

| | FY 1982 (actual) | FY 1983 (estimate) | FY 1984 (estimate) |
|---|---|---|---|
| **Measurement and engineering research and standards:** | **$157.1** | **$166.7** | **$151.5** |
| Measurement research and standards | 77.3 | 79.5 | 80.5 |
| Engineering measurements and standards | 45.2 | 48.3 | 45.4 |
| Computer sciences and technology | 13.2 | 11.4 | 5.0 |
| Core measurement research for new technologies | 14.0 | 19.2 | 18.5 |
| Fire research | 7.4 | 8.3 | 2.1 |
| **Competence and central technical support:** | **15.8** | **26.1** | **15.7** |
| Technical competence fund | 7.4 | 7.0 | 7.7 |
| Central technical support | 8.4 | 19.1 | 8.0 |
| **Total NBS** | **172.9** | **192.8** | **167.2** |

# Directory

TECHNICAL work at NBS is carried out in the National Measurement Laboratory, the National Engineering Laboratory, and the Institute for Computer Sciences and Technology. These groups are supported by the Office of the Director of Administration; the Office of the Director, NBS/Boulder Laboratories; and the Office of the Associate Director for Programs, Budget, and Finance. This amalgam of people and programs forms a community dedicated to service. An interdisciplinary approach allows NBS to provide the Nation with scientific measurements of high precision and accuracy, coupled with solutions for current and future technological problems.

This report has only highlighted some of the Bureau's programs. For more information on specific projects, contact the people listed in this directory. To reach members of the Gaithersburg, MD, staff, dial (301) 921 + extension or write to the National Bureau of Standards, Washington, DC 20234. Bureau staff located in Boulder, CO, can be contacted on (303) 497 + extension noted in the directory, or write to the National Bureau of Standards, Boulder, CO 80303. Boulder staff members are designated in the directory with asterisks.

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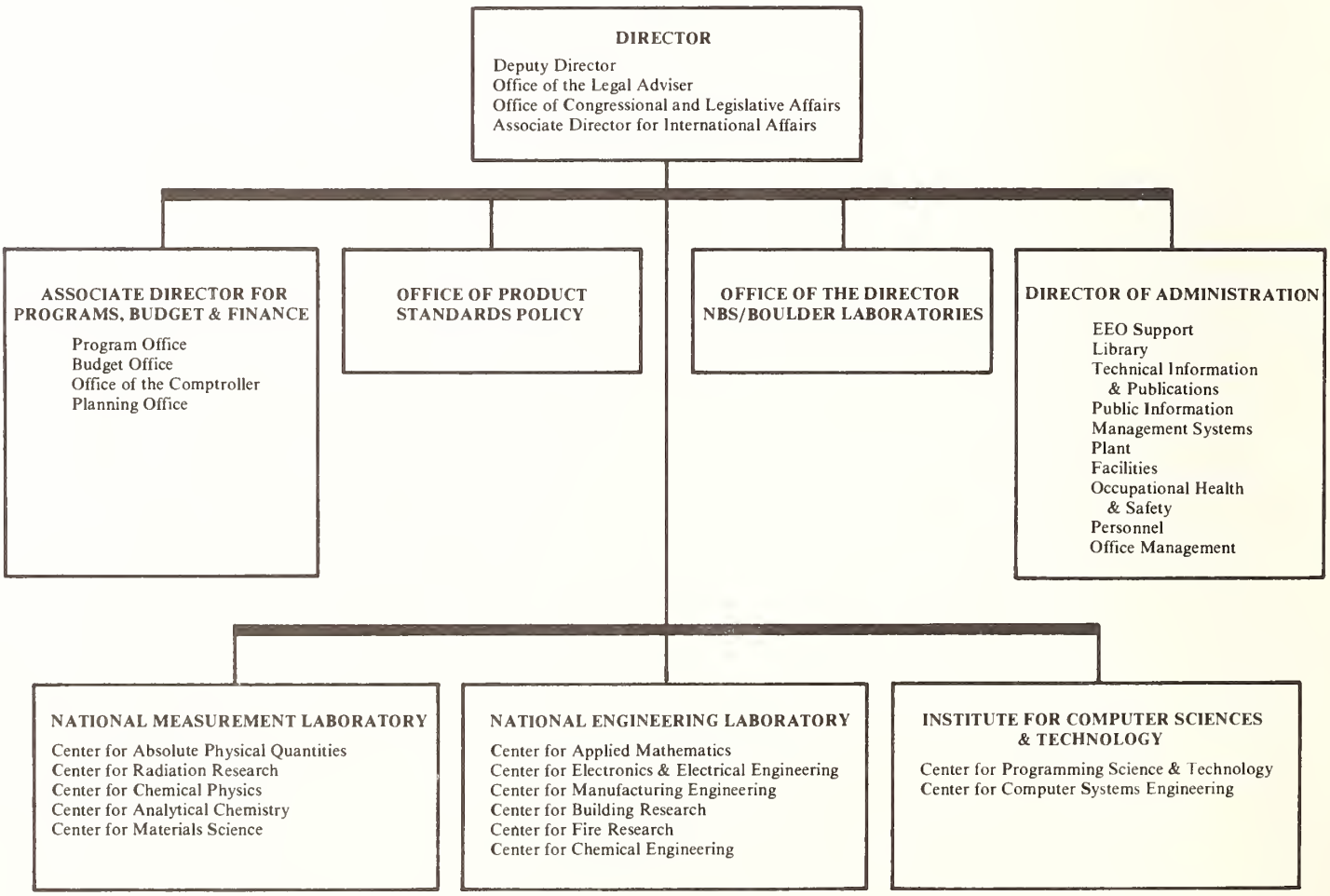

## *Office of the Associate Director for Programs, Budget, and Finance*

The Office of the Associate Director for Programs, Budget, and Finance plans, develops, and evaluates Bureau-level programs and formulates and carries out policies and strategies for programmatic, budgetary, and financial matters. It develops techniques for and coordinates the review of technical and overhead programs; serves as the NBS Director's staff for Bureau-level, programmatic budget formulation and execution and finance matters; and develops and maintains mechanisms to monitor planned and actual uses of resources by providing integrated, evaluated information on program progress, opportunities, and resources to the NBS Director. In addition, the Office advises management on significant changes and deviations and recommends program, budget, finance, and accounting priorities to the NBS Director.

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The Office of the Director of Administration directs the management of Bureau-wide facilities and information and administrative systems including information and office services, procurement, technical and public information functions, personnel, management consulting services, health, safety, and security functions, as well as physical plant, facilities, and space management. The Office also decides on policies and plans and directs actions to assure the responsiveness of these services to the needs of the technical programs.

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## *Office of the Director NBS/Boulder Laboratories*

The Office of the Director, NBS/Boulder Laboratories, which is located in Boulder, CO, provides support to the technical programs of the NBS/Boulder Laboratories. These laboratories conduct research on measurement science for the National Measurement Laboratory in time and frequency, quantum physics, thermodynamics, and materials science. The laboratories also carry out programs for the National Engineering Laboratory in electromagnetics, thermophysical properties, and fluid dynamics.

Dr. Robert A. Kamper, Director (3237)*

## *National Measurement Laboratory*

The National Measurement Laboratory provides the national system of physical, chemical, and materials measurement; coordinates the system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce. It conducts materials research leading to improved methods of measurement, standards, and data on the properties of materials needed by industry, commerce, educational institutions, and government. NML also furnishes advisory and research services to other government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides standard reference data and calibration services.

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The Institute for Computer Sciences and Technology develops computer standards, conducts research, and provides scientific and technical services to aid Federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in government operations in accordance with Public Law 89-306, relevant Executive Orders, and other directives. ICST manages a government-wide program for standards development and use, including management of Federal participation in ADP voluntary standardization activities.

In addition, ICST provides technical support in: the development of Federal ADP management and procurement policies, the selection and direction of Federally sponsored computer research and development, and the resolution of computer utilization issues.

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The National Engineering Laboratory furnishes technology and technical services to users in the public and private sectors to address national needs and to solve national problems in the public interest. NEL conducts research in engineering and applied science in support of these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical services; and develops engineering data and measurement capabilities. NEL also provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user.



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